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ELECTRICAL, HIGH TEMPERATURE TEST PROBE WITH CONDUCTIVE DRIVEN GUARD

CROSS-REFERENCE TO RELATED APPLICATION

This patent application claims priority to U.S. Provisional Patent Application, Serial
10 Number 60/458,467, filed on March 28, 2003, and is related to U.S. Utility Patent Application,
Serial Number, 09/730,130, filed December 4, 2000, entitled "PROBE TILE FOR PROBING
SEMICONDUCTOR WAFER"; U.S. Provisional Patent Application, Serial Number
60/392,394, filed June 28, 2002, entitled "SHIELDED PROBE APPARATUS FOR PROBING
SEMICONDUCTOR WAFER"; and U.S. Utility Patent Application, Serial Number 10/383,079,
15 filed March 6, 2003, entitled "APPARATUS AND METHOD FOR TERMINATING PROBE
APPARATUS OF SEMICONDUCTOR WAFER"; the subject matter of which are incorporated
herewith by reference.

FIELD OF THE INVENTION

20 The present invention relates generally to semiconductor test equipment, and more
particularly, to a probe apparatus used in semiconductor test equipment for electrically probing
devices on a semiconductor wafer.

BACKGROUND OF THE INVENTION

25 The semiconductor industry has a need to access many electronic devices on a
semiconductor wafer. As the semiconductor industry grows and devices become more complex,
many electrical devices, most commonly semiconductor devices, must be electrically tested, for
example, for leakage currents and extremely low operating currents. These currents are often
below 100fA. In addition, the currents and device characteristics are often required to be
30 evaluated over a wide temperature range to understand how temperature affects a device. Also,
because of materials characteristics of dielectrics, it is often difficult to test characteristics of
semiconductor devices in a wide operating temperature range.

To effectively measure at currents below 100fA (Femto Ampere), a measurement signal
must be isolated from external electrical interference, leakage currents through the dielectric

5 material, parasitic capacitance, triboelectric noise, piezoelectric noise, and dielectric absorption, etc.

Accordingly, there is a need for improved semiconductor test equipment for electrically probing semiconductor devices at low currents over a wide temperature range.

10 SUMMARY OF THE INVENTION

To solve the above and the other problems, the present invention provides a probe needle apparatus and method including a driven guard having the same potential as a probe needle for reducing signal noise in low current measurements. The probe needle apparatus includes a central conductive probe needle covered with alternating layers of dielectric and conductive materials.

In one embodiment, the probe needle apparatus comprises a central conductive probe needle surrounded by a high temperature dielectric layer of material. A conductive layer is deposited around the dielectric layer to provide a driven guard. The initial layer of dielectric material provides a thin and continuous barrier to prevent the conductive driven guard from contacting electrically to the probe needle. In one embodiment, a subsequent protective layer is applied over the driven guard.

In one embodiment of the present invention, the probe needle can be a probe needle disclosed in U.S. Provisional Patent Application, Serial Number, 60/392,394, filed June 28, 2002, entitled "SHIELDED PROBE APPARATUS FOR PROBING SEMICONDUCTOR WAFER". Also, in one embodiment, the probe needle is masked at the distal and proximate ends to allow continuity. The masked probe needle is then coated with a flexible high temperature dielectric, prior to being coated with a conductive layer, such as gold, for the driven guard. An optional top layer can be applied by a method, such as dipping and spinning, or depositing by other means to protect the outer conductive layer.

30 In one embodiment of the probe needle, an initial dielectric layer is applied by dipping and spinning. After thermally curing the dielectric layer, the conductive layer for the driven guard is applied.

Additionally in one embodiment of the present invention, the probe needle may be coated with an initial dielectric layer of SiO₂. A thin conductive layer of the driven guard may be strengthened by over-plating.

5 These and other features of the present invention will become apparent to those skilled in
the art from the following detailed description, wherein it is shown and described illustrative
embodiments of the invention, including best modes contemplated for carrying out the invention.
As it will be realized, the invention is capable of modifications in various obvious aspects, all
without departing from the spirit and scope of the present invention. Accordingly, the drawings
10 and detailed description are to be regarded as illustrative in nature and not restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a cross sectional view of one embodiment of a shielded probe apparatus in
accordance with the principles of the present invention.

15 Figure 2 is a masking technique for masking a shielded probe in accordance with the
principles of the present invention.

Figure 3 is a rotational technique for applying one or more conformal coatings on the
shielded probe in accordance with the principles of the present invention.

Figure 4 is a cross sectional view of another embodiment of a shielded probe apparatus in
20 accordance with the principles of the present invention.

Figure 5 is a perspective view of one embodiment of a probe apparatus having a co-axial
shielded probe terminating with a co-axial signal cable at a terminating device, in accordance
with the principles of the present invention.

Figure 6 is a perspective view of one embodiment of a probe apparatus having a tri-axial
25 shielded probe terminating with a tri-axial signal cable at a terminating device, in accordance
with the principles of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the following description of a preferred embodiment, reference is made to the
30 accompanying drawings, which form a part hereof, and in which is shown by way of illustration
a specific embodiment in which the invention may be practiced. It is to be understood that other
embodiments may be utilized and structural changes may be made without departing from the
scope of the present invention.

For purposes of explanation, numerous specific details are set forth in the following
35 description in order to provide a thorough understanding of the present invention. However, it

5 will be evident to one of ordinary skill in the art that the present invention may be practiced without some of these specific details.

While this invention is susceptible of embodiment in many different forms, there is shown in the drawings and will herein be described in detailed preferred embodiment of the invention with the understanding that the present disclosure is to be considered as an
10 exemplification of the principles of the invention and is not intended to limit the broad aspect of the invention to the embodiment illustrated.

The numerous innovative teachings of the present application will be described with particular reference to the presently preferred embodiments, wherein these innovative teachings are advantageously applied to the particular problems of a probe needle for measuring low
15 currents with a wide operating temperature range in probing a semiconductor device. However, it should be understood that these embodiments are only examples of the many advantageous uses of the innovative teachings herein. In general, statements made in the specification of the present application do not necessarily limit any of the various claimed inventions. Moreover, some statements may apply to some inventive features but not to others. In general, unless
20 otherwise indicated, singular elements may be in the plural and visa versa with no loss of generality.

The following terms are particularly described throughout the description:

Semiconductor Device Not Limitive

25 The present invention is particularly suitable for probing semiconductor devices, but the use of the present teachings is not limited to probing semiconductor devices. Other devices may be applied to the present invention teachings. Thus, while this specification speaks in terms of probing 'semiconductor' devices, this term should be interpreted broadly to include probing any suitable device.

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Low Current Not Limitive

The present invention solves the problem of measuring currents below 100 fA, but the current range of the present teachings is not limited to below 100 fA. For example, the present invention may be applied to measure the currents at or above 100 fA in a semiconductor device.
35 Thus, while this specification speaks in terms of 'low currents' or 'measuring currents below 100

5 fA', these terms should be interpreted broadly to include any current that flows through a semiconductor device which could be at or above 100 fA. In a grounded guard controlled impedance configuration the present invention also solves the problem of measuring high frequency signals at high temperatures.

10 Wide Temperature Not Limitive

The present invention solves the problem of measuring currents of a semiconductor device in a narrow or limited operating temperature range. The present teachings do not limit to a specific operating temperature range. The present application allows a tester to electrically probe semiconductor devices over a wide operating temperature range, not only at a low
15 operating temperature but also a high operating temperature, e.g. an operating temperature up to 300C and beyond. Thus, while this specification speaks in terms of 'wide temperature range' or 'measuring currents in a wide operating temperature range', these terms should be interpreted broadly to include any suitable operating or testing temperature range of a semiconductor device.

20 Probe Not Limitive

The present invention solves the problem of measuring currents of a semiconductor device using a co-axial or a tri-axial shielded probe. However, nothing in the teachings of the present invention limits application of the teachings of the present invention to a probe needle with more or less layers. Advantageous use of the teachings of the present invention may be had
25 with a probe needle of any number of layers.

Signal Cable Not Limitive

The present invention solves the problem of measuring currents of a semiconductor device using a co-axial or a tri-axial signal cable. However, nothing in the teachings of the
30 present invention limits application of the teachings of the present invention to a signal cable with more or less layers. Advantageous use of the teachings of the present invention may be had with a signal cable of any number of layers.

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5 Metals Not Limitive

Throughout the discussion herein there will be examples provided that make reference to metals in regards to needle and driven guard. The present invention does not recognize any limitations in regards to what types of metals may be used in affecting the teachings of the present invention. One skilled in the art will recognize that any conductive material may be used
10 with no loss of generality in implementing the teachings of the present invention.

Dielectric Not Limitive

Throughout the discussion herein there will be examples provided that make reference to dielectric. The present invention does not recognize any limitations in regards to what types of
15 dielectric may be used in affecting the teachings of the present invention. One skilled in the art will recognize that any non-conductive, highly heat-resistant material may be used with no loss of generality in implementing the teachings of the present invention.

Exemplary Embodiment

20 As shown in Figure 1, a shielded probe needle apparatus 100 includes a probe needle 101 covered with a dielectric layer 102, a conductive driven guard layer 103, and an optional protective coating layer 104. The dielectric layer 102 and the optional protective coating layer 104 are preferably applied to the probe needle 101 using a physical/chemical vapor deposition (P/CVD) of high temperature polymer.

25 As also shown in Figure 1, the connection or contact between the probe needle 101 side and the connector or signal cable 107 side is head on head. Alternatively, the connection or contact between the probe needle 101 side and the connector or signal cable 107 side is side-by-side as shown in Figures 5 and 6, which are disclosed in U.S. Utility Patent Application, S/N 10/383,079, filed March 6, 2003, subject matter of which are incorporated herewith by reference.
30 Figure 2 illustrates a masking technique for masking a probe needle 201. As shown, masking materials 202 and 203 are applied to the ends of the probe needle 201 to prevent the conductive driven guard layer 103, such as the conductive driven guard layer 103 in Figure 1, from depositing over the end of the dielectric creating a conductive path between the conductive guard layer 103 and the probe needle 201. The masks are applied towards the ends of the probe needle
35 necessary to provide required access and protection.

5 Alternate methods may be used to achieve at least similar masking functions to prevent electrical contact between the conductive driven guard layer 103 and the probe needle 201, and to provide required access and protection to the probe needle. For example, in one exemplary method, the end of the conductive driven guard layer is removed by ablation or chemical etch to prevent the conductive driven guard layer, such as the conductive driven guard layer 103 in
10 Figure 1, from remaining on the dielectric creating a conductive path between the conductive guard layer and the probe needle 201. The protective coating 104 is applied over the conductive driven guard layer to provide required access and protection. The mask is then removed or can be left behind as the protective layer.

 Figure 3 illustrates a rotational curing technique for coating the shielded probe with
15 dielectric or the conductive guard layer. As shown, a plurality of probe needles 301 are mounted radially on an axially rotational rod 304 by devices, such as clamps 302. A layer is uniformly applied to the probe needles by dipping or spraying and then spinning the probe needles. The masks at the ends of the probe needle also prevent the protective coating layer from touching the probe needle. Alternatively, the masking is not used and the layer is removed by mechanical or
20 chemical means. Uniformly coated materials can be deposited and dried by a flow of thermally conditioned and humidity controlled gas.

 Further, in another alternative technique, a mask is applied one end, e.g. a proximal end (the back end) of the probe needle. After a dielectric layer is applied over the probe needle, e.g. a P/CVD layer is deposited over the probe needle, another mask is applied to the other end, e.g. a
25 distal end (the tip end) of the probe needle. Next, a conductive layer, such as gold, is sputtered over the dielectric layer.

 Figure 4 illustrates one embodiment of a probe needle apparatus 400 in a tri-axial configuration. Figure 1 illustrates one embodiment of the probe needle apparatus 100 in a coaxial configuration. As shown in Figure 4, the probe apparatus 400 comprises a probe needle
30 401, a base dielectric layer 402 covering the probe needle 401, a conductive guard layer 403 covering the base dielectric layer 402 which is in turn covered by a second dielectric layer 404, and a second conductive guard layer or an outer guard layer 405 covering the second dielectric layer 404. A nonconductive protective layer 406 may be added for electrical and mechanical protection.

5 As briefly discussed above, Figure 5 shows an embodiment of a probe apparatus having a
co-axial shielded probe terminating with a co-axial signal cable at a terminating device side by
side. The following detailed descriptions have been disclosed in U.S. Utility Patent Application,
S/N 10/383,079, filed March 6, 2003, subject matter of which are incorporated herewith by
reference. In Figure 5, a probe apparatus 100a includes a co-axial shielded probe 108a
10 terminating with a co-axial signal cable 102a at a terminating device 132. The shielded probe
108a includes a center conductive probe needle 146a, a dielectric layer 148a surrounding the
center conductive probe needle 146a, a conductive guard layer 150a surrounding the dielectric
layer 148a, a non-conductive heat-shrinkable sleeve 152a surrounding the conductive guard layer
150a. The signal cable 102a includes a center signal conductor 154a, a dielectric layer 156a
15 surrounding the center signal conductor 154a, a conductive dispersion/guard layer 158a
surrounding the dielectric layer 156a, and a non-conductive heat-shrinkable sleeve 160a
surrounding the conductive dispersion/guard layer 158a.

 At a distal end 126a, the shielded probe 108a extends from the dielectric block 130
toward the bond pad 110. The sleeve 152a is removed when it is inserted into the dielectric
20 block 130.

 As shown in Figure 5, at the proximal end 128a, the center conductive probe needle 146a
of the shielded probe 108a is disposed side by side with and electrically connects to the center
signal conductor 154a of the signal cable 102a. The dielectric layer 148a of the shielded probe
108a is disposed side by side with and connects to the dielectric layer 156a of the signal cable
25 102a. The conductive guard layer 150a of the shielded probe 108a is disposed side by side with
and electrically connects to the conductive dispersion/guard layer 158a of the signal cable 102a.
The sleeve 152a of the shielded probe 108a is disposed side by side with and connects to the
sleeve 160a of the signal cable 102a.

 As shown in Figure 5, the terminating device 132 includes a shrink tube 162a for shrink-
30 tubing the sleeve 152a of the shielded probe 108a and the sleeve 160a of the signal cable 102a
together, for shrink-tubing the conductive guard layer 150a of the shielded probe 108a and the
conductive dispersion/guard layer 158a of the signal cable 102a together, for shrink-tubing the
dielectric layer 148a of the shielded probe 108a and the dielectric layer 156a of the signal cable
102a together, and for shrink-tubing the center conductive probe needle 146a of the shielded

5 probe 108a and the center signal conductor 154a of the signal cable 102a together. The shrink tube 162a is covered by the strain relief 144a.

An extension 164a of the shrink tube 162a is disposed at an end of the center conductive probe needle 146a and the center signal conductor 154a, and is configured sufficiently wide enough to prevent electrical current from leaking from the center conductive probe needle 146a and the center signal conductor 154a to the strain relief 144a. In addition, the center conductive probe needle 146a and the center signal conductor 154a may be soldered, brazed, welded, crimped, or snuggled therebetween at 166a to provide additional clearance between the center conductive probe needle 146a and the strain relief 144a, and additional clearance between the center signal conductor 154a and the strain relief 144a.

15 Similarly, as briefly discussed above, Figure 6 shows an embodiment of a probe apparatus 100b having a tri-axial shielded probe terminating with a tri-axial signal cable at a terminating device side by side. The following detailed descriptions have been disclosed in U.S. Utility Patent Application, S/N 10/383,079, filed March 6, 2003, subject matter of which are incorporated herewith by reference. In Figure 6, the probe apparatus 100b includes a tri-axial shielded probe 108b terminating with a tri-axial signal cable 102b at the terminating device 132. The tri-axial shielded probe 108b additionally includes a second dielectric layer 168 sandwiched between a conductive guard layer 150b and the sleeve 152b. A guard layer 169 may be included between the second dielectric layer 168 and the sleeve 152b. The signal cable 102b additionally includes a second dielectric layer 170 sandwiched between the conductive dispersion/guard layer 158b and the sleeve 160b. A guard layer 171 may be included between the second dielectric layer 171 and the sleeve 160b. Accordingly, as shown in Figure 6, the shielded probe 108b includes a center conductive probe needle 146b, a dielectric layer 148b surrounding the center conductive probe needle 146b, the conductive guard layer 150b surrounding the dielectric layer 148b, the second dielectric layer 168 surrounding the conductive guard layer 150b, the guard layer 169 surrounding the second dielectric layer 168, and the sleeve 152b surrounding the guard layer 169. The signal cable 102b includes a center signal conductor 154b, a dielectric layer 156b surrounding the center signal conductor 154b, the conductive dispersion/guard layer 158b surrounding the dielectric layer 156b, the second dielectric layer 170 surrounding the conductive dispersion/guard layer 158b, the guard layer 171 surround the second dielectric layer 170, and the sleeve 160b surrounding the guard layer 171.

5 At a distal end 126b, the shielded probe 108b extends from the dielectric block 130 toward the bond pad 110. The sleeve 152b is removed when it is inserted into the dielectric block 130.

 As shown in Figure 6, at the proximal end 128b, the center conductive probe needle 146b of the shielded probe 108b is disposed side by side with and electrically connects to the center
10 signal conductor 154b of the signal cable 102b. The dielectric layer 148b of the shielded probe 108b is disposed side by side with and connects to the dielectric layer 156b of the signal cable 102b. The conductive guard layer 150b of the shielded probe 108b is disposed side by side with and electrically connects to the conductive dispersion/guard layer 158b of the signal cable 102b. The second dielectric layer 168 of the shielded probe 108b is disposed side by side with and
15 connects to the second dielectric layer 170 of the signal cable 102b. The guard layer 169 of the shielded probe 108b is disposed side by side with and electrically connects to the guard layer 171 of the signal cable 102b. The sleeve 150b of the shielded probe 108b is disposed side by side with and connects to the sleeve 160b of the signal cable 102b.

 As shown in Figure 6, the terminating device 132 includes a shrink tube 162b for shrink-
20 tubing the sleeve 152b of the shielded probe 108b and the sleeve 160b of the signal cable 102b together, for shrink-tubing the second dielectric layer 168 of the shielded probe 108b and the second dielectric layer 170 of the signal cable 102b together, for shrink-tubing the conductive guard layer 150b of the shielded probe 108b and the conductive dispersion/guard layer 158b of the signal cable 102b together, for shrink-tubing the guard layer 169 of the shielded probe and
25 the guard layer 171 of the signal cable 102b, for shrink-tubing the dielectric layer 148b of the shielded probe 108b and the dielectric layer 156b of the signal cable 102b together, and for shrink-tubing the center conductive probe needle 146b of the shielded probe 108b and the center signal conductor 154b of the signal cable 102b together. The shrink tube 162b is covered by the strain relief 144b.

30 An extension 164b of the shrink tube 162b is disposed at an end of the center conductive probe needle 146b and the center signal conductor 154b, and is configured sufficiently wide enough to prevent electrical current from leaking from the center conductive probe needle 146b and the center signal conductor 154b to the strain relief 144b. In addition, the center conductive probe needle 146b and the center signal conductor 154b may be soldered, brazed, welded,
35 crimped, or snuggled therebetween at 166b to provide additional clearance between the center

5 conductive probe needle 146a and the strain relief 144b, and additional clearance between the
center signal conductor 154a and the strain relief 144b.

From the above description and drawings, it will be understood by those of ordinary skill
in the art that the particular embodiments shown and described are for purposes of illustration
only and are not intended to limit the scope of the present invention. Those of ordinary skill in
10 the art will recognize that the present invention may be embodied in other specific forms without
departing from its spirit or essential characteristics. References to details of particular
embodiments are not intended to limit the scope of the invention.

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